New Window on the Extreme Universe

Are these gamma-ray sources generating cosmic rays?

When we gaze at the stars, the light we see is radiation from hot gas on the stellar surfaces, continuously heated by nuclear fusion at the centers of those stars. Recently, scientists at Los Alamos have developed a technique to survey the entire overhead sky for sources of much higher energy radiation, gamma rays at energies trillions of times higher than the energy of the starlight we see with our eyes.

Those gamma rays come from regions of violent activity, where unknown mechanisms accelerate matter to high energies. They come from the active centers of distant galaxies, where stars are being swallowed up by supermassive black holes, and solar-system-size clouds of hot ionized matter are being ejected in narrowly focused jets moving at nearly the speed of light. They also come from expanding nebulae left over from exploding stars (supernovae), wind nebulae streaming from compact neutron stars, and stellar-size objects that produce short, ultrabright bursts of gamma rays.

Understanding these rapidly changing regions and how they generate high-energy gamma rays presents us with some of the most-difficult problems in modern physics. For example, are these gamma-ray sources also generating cosmic rays, the very high energy charged nuclei that streak across the galaxy?

"The regions emitting gamma rays have intense gravitational, electric, and magnetic fields," says Brenda Dingus, current team leader of the Milagro project, the high-energy gamma-ray experiment at Los Alamos. "In our work at Milagro, we and our university collaborators have been surveying the sky for the very highest energy gamma rays, those with energies of 10- to 100-trillion electron volts (TeV) and higher. These gamma rays can tell us the most about these violent regions and thereby put constraints on our ideas about the acceleration mechanisms that might be taking place there."

Locating these gamma-ray sources might also help solve the century-old mystery of how and where cosmic rays are formed. Gamma rays, like visible light, travel to Earth in straight lines and therefore reveal their place of origin. In contrast, the electrically charged cosmic rays get deflected by the magnetic fields in our galaxy and arrive at Earth from all directions with no indication of where they come from.

"Cosmic rays form a large, uniform background. To detect a gamma-ray source, we must detect a significant number of gamma rays coming from a particular direction, a number larger than the fluctuations in the cosmic-ray background," continues Gus Sinnis, co-spokesperson for Milagro and leader of the Neutron Science and Technology Group. "Because gamma rays are likely ‘fellow travelers' of cosmic rays, in the sense that they are produced with them or by them, a high-energy gamma-ray source is likely to be at or near a cosmic-ray source. If one finds the former, one is likely closing in on the latter."